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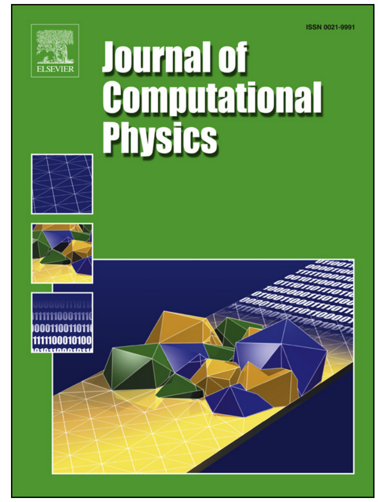

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An Entropy-Variables-based formulation of Residual Distribution Schemes for Non-Equilibrium Flows

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Abstract

In this paper we present an extension of Residual Distribution techniques for the simulation of compressible flows in non-equilibrium conditions. The latter are modeled by means of a state-of-the-art multi-species and two-temperature model.

An entropy-based variable transformation that symmetrizes the projected advective Jacobian for such a thermophysical model is introduced. Moreover, the transformed advection Jacobian matrix presents a block diagonal structure, with mass-species and electronic-vibrational energy being completely decoupled from the momentum and total energy sub-system.

The advantageous structure of the transformed advective Jacobian can be exploited by contour-integration-based Residual Distribution techniques: established schemes that operate on dense matrices can be substituted by the same scheme operating on the momentum-energy subsystem matrix and repeated application of scalar scheme to the mass-species and electronic-vibrational energy terms.

Finally, the performance gain of the symmetrizing-variables formulation is quantified on a selection of representative testcases, ranging from subsonic to hypersonic, in inviscid or viscous conditions.

Keywords:

computational fluid dynamics, residual distribution schemes, hypersonic flow, entropy variables, thermo-chemical non-equilibrium, unstructured grids